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Installation-Wide GIS Implementation Issues

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Foreword

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Contents

1 Introduction

Background

Geographic information systems (GIS) have been implemented at nearly every U.S. Army installation in the United States. It is estimated that the Federal government spends over $3 billion annually on the acquisition and management of spatial data. Numerous Federally initiated and supported efforts are focused on issues of data management and dissemination, particularly in the areas of data catalogs and clearinghouses.

In spite of the large investments in GIS technology and software, implementation has typically occurred in more of an ad hoc manner than preferred, and more decentralized or "grass-roots" initiated than from a comprehensive information resource management perspective. In large part this is due to the technological evolution of software and network technologies from stand-alone Unix workstations to the ubiquitous desktop PC and Internet connectivity.

Some of the problems inherent with this history include insufficiently documented data, redundant and divergently evolving data, incompatible system and file formats, and a disconnect between the capabilities and expectations of a growing user community, and the individuals and organizations historically managing these resources.

The information systems (IS) industry has addressed some of these historic problems by development and use of a technology called Enterprise information models. The notion of Enterprise GIS borrows from Enterprise information models. The objective of Enterprise GIS is to create a comprehensive framework for providing for user information needs and minimizing problems due to the distributed and disaggregated implementation (Strand 1999).

Objective

The objective of this research was to outline the characteristics of Enterprise GIS implementation on an installation, identify potential issues, and provide initial guidance in the process of examining the need for an enterprise, or installation-wide solution.

Approach

The principal approach used in meeting this research objective was to review literature concerning issues of implementation and management of Enterprise GIS data sets. Literature included academic studies of implementation and evaluation factors, as well as popular media to provide a more “client centered” examination. This report is intended to be a starting point for investigating options for improving the efficiency and effectiveness of geographic information services on Army Installations.

Mode of Technology Transfer

This research will be made available to the Information Systems (IS) staff via the Internet. It is expected that IS researchers will use this information in future evaluations of data management and Enterprise information models.

2 Enterprise GIS

Enterprise GIS is a term used to describe a geographical information system (GIS) that is able to support an entire organization, promoting coordinated geospatial data development and access across organizational and departmental boundaries. In an Enterprise GIS, data is stored and updated in a database that is accessible to appropriate staff. Access to data is managed through interfaces designed for different user communities, from administrators, to analysts, to end-users. Most information system implementations benefit from data accessibility across a network to eliminate redundant updating efforts, eliminate inconsistency in geographic information, and provide and receive data from all departments.

An Enterprise GIS also functions as a distributed database, used and shared by many users. Distribution avoids duplication of effort for database development and maintenance (Worrall 1994). The Enterprise GIS model can provide a better understanding of an organization's data and user relationships, and can lead to new ways of viewing and maintaining data (Wilson 1996). The departments currently responsible for the maintenance of core data can continue upkeep, posting the updates for access by all departments. This promotes an acknowledgement of distributed roles and responsibilities across an installation while coordinated authority for all core data creates a mechanism that can support GIS expansion, management, and increased data acceptance procedures. These considerations should lead to the adoption of standards across departments. While there still may be individual departmental GIS serving project-based analysis and departmental collection, the unified database concept allows for both data distribution and integration, while serving as a direct support for departmental functions.

Development of an Enterprise GIS can build on existing and emerging distributed computing technology to provide capabilities that are widely available, reliable, and scalable across a variety of platforms. Individual users may access a range of products to support GIS applications. Existing expertise, staff experience, and resources are used, as well as past and future investments in hardware, software, and data. This maximizes expertise and human resources and improves the overall cost effectiveness. It also allows for shared hardware and software, assuring that the best technology available is used to enhance the integration and handling of data from a variety of sources (Worrall 1994).

Although there are important differences between the structure of information management within an Army installation and the corporate environment for which most enterprise systems are directed, it is assumed that the similarities are sufficient to use the model of Enterprise information systems for an initial investigation.

Guidelines and Issues in Installation-Wide GIS

A broad range of technical and organizational issues surround the successful implementation of GIS within an installation. Technical issues focus on computing capability located when, where, and to whom it is needed, managing data currency and accuracy, and security. Organizational issues focus on distributed responsibilities across units that have no common chain of command, provision of sufficient training, provision of sufficient staff resources, and competition among stakeholders, to name a few (Struck and Dilks 1998). Although any one of these issues could serve as a departure point for planning, establishing a set of goals for the GIS development in an organization is a necessary first step.

Goals

The general consensus of the literature regarding planning for an enterprise solution for GIS uses the sequence of goal formulation, needs assessment, hardware and software constraints, design of a unified data model, implementation, and review. Because goals form the foundation for getting the necessary resources, they require support of the top management. Examples of goals include: reengineering existing workflows to create a more efficient and effective operation, or using GIS technology to develop a single source, cost effective, seamless, and accurate base map that will serve as the base standard for all geographically associated data. During planning it is also necessary to get commitments from a number of departments in an organization. The plan needs to include objectives that define what changes the organization would like to see over the next 3- to 5-year period. These objectives establish the baseline requirements for the system design review.

Needs Assessment

A needs assessment identifies current and potential stakeholders in GIS at an installation. Stakeholders include GIS managers, analysts and support staff, and users. The needs assessment identifies the reasons for using a GIS and includes specific references to applications (e.g., produce a base map for a unit exercise, record maintenance activities, or inventory species diversity and abundance).

The goal of the needs assessment is to identify current facilities and entities, review existing information systems, determine the application requirements, and identify data resources within an organization. This must be done before evaluating hardware requirements because the needs help determine the optimum hardware requirements.

Once the application needs are understood, the user community needs to identify the locations and the number of users who will need access to the application, and the frequency with which they will be using the system. This step can be done either by internal GIS staff or a GIS consultant by having direct discussions with selected user representations. The step may be outlined as:

1. Identify GIS users throughout the organization by interviewing department staff. Note GIS user locations and departments. Users include managers, system administrators, database administrators, programmers, processors, analysts, cartographers, drafters, technicians, and end users.
2. Identify the GIS applications needs and data requirements.
3. Evaluate the potential benefits of implementing GIS solutions.
4. Identify requirements for supporting the applications and data development.
5. Propose an implementation schedule.

Issues with Needs Assessment

The needs assessment is a consensus-building report that documents the mapping, application, and technology needs of stakeholders within the organization. An effective assessment requires involvement and support within the organization, especially from the decisionmakers authorized to provide the resources and direction for an effort. A cost-benefit analysis with a pilot project would demonstrate the benefits of the needs assessment to the organization.

Hardware and Software Issues

GIS, unlike other computing products that have become commodity products (such as word processing or spreadsheets) are computationally demanding. Demand points include the storage and processing of large data files (100's of megabytes to gigabyte files), complex analysis (surface fitting, interpolation, and other geostatistical operations), and visualization (2- and 3-dimensional rendering). Consequently, there is a wide range of computer requirements depending on the needs and responsibilities of the user, ranging from browsing and viewing of prepared maps, to intense analysis and management of the data. This diversity is only recently enabled through development of lower level versions of complete GIS software packages that focus on (if not optimize for) particular tasks.

Hardware Issues

Network communications is an important issue for a distributed GIS. The availability of networking reveals problems inherent with disconnected GIS data management issues, but is also an essential part of the solution. It is assumed that the requirement for an installation-wide GIS is insufficient, in and of itself, to generate support for network implementation where none currently exists; but the installation-wide GIS should influence the design and capacity specifications for an installation's network environment. Local area network standards for the organization will provide a starting point. The type of network communication needed between the various locations will determine system capacity, including the maximum network bandwidth. These factors are based on anticipated network traffic, file size, and level of service desired.

Computer hardware is available in several different platforms and operating systems. Determine a platform and operating system or combination of platforms and operating systems to use in the organization. First review the existing computer environment. Determine if established preferences exist or if there are existing relationships to current vendors. Check to see how the existing computers are maintained and if many hours of staff training were put into the existing computer system. Again it is important to stress that one of the outcomes of the microcomputer "revolution" is the ability to deploy different computational resources based on user requirements. Thus, not all users will need workstation environments. Indeed, for many a simple PC with an Internet browser is sufficient. Thus it is important to recognize and plan for the full range of GIS system users. Once the existing computer system has been assessed, establish uniform hardware policies and standards for future purchases.

Worrall (1994) describes two strategies for identifying any operational constraints and priorities. Information system strategy is a strategy used to determine what systems are necessary to support and maintain the information needs (derived from the needs assessment) and the nature of the inter-relationships between those systems. Issues to consider are system availability and security requirements (such as firewalls) or specific needs for maintaining application performance. Information technology strategy is a strategy that recognizes the support (i.e., system and network administration experience/staff) needed for the required systems and how the information will be transferred to the end-users. Enterprise systems need to be able to handle both the GIS workload (i.e., processing requirements, data volume/complexity, etc.) and the end-user demands (i.e., transaction management) to operate successfully.

Software Issues

In reality, the choice of a software environment will be determined by existing agreements, and previous use. Historically, this could be problematic if different communities within an organization selected software that was fundamentally incompatible. However, recent trends in software increases interoperability between software vendors and their proprietary data types via native readers and translation software. Although software diversity still involves extra management, such diversity may better support user needs than a monolithic policy, as long as sufficient effort is directed toward common data models and other metadata issues. Table 1 lists some of the currently available GIS software products. If large databases need to be maintained, a relational database management system (RDBMS) may be needed. Some established RDBMSs are Oracle, DB2, INFORMIX, and SYBASE. Many GIS systems can communicate with relational database products via vendor-specific protocols or through an interoperability standard such as ODBS (Open Data Base Specification).

Data Model

A unified data model is just as important as the choice of hardware and software. The data model enables departments to use each other's data. Often when an organization needs to examine problems or possible problems and determine their causes, they may need data from multiple systems.

The data warehouse is contained within the data model. It groups information into tables. A data warehouse is designed to store and retrieve data and is built to contain enterprise-wide information collected from multiple operational sources. It can be thought of as a storage space for information that comes from different systems across the installation, bringing data to one place where users can view and analyze the data to support the decisions they make every day. It may not be necessary to *physically* collect the data onto one physical system, but a unified user view is required. One advantage of a data warehouse is that managers can look at installation-wide trends and patterns and make better-informed decisions about information management policies that affect the entire installation.

Table 1: GIS Software Systems.

GIS Software

Vendor	Products: Stand-Alone Viewer	Products: Desktop Mapping	Products: Full-Function GIS	Products: Intra-net Servers	Server Platform	Supported Data Formats	System Requirements	Support
Autodesk Inc. 111 McInnis Parkway San Rafael, CA 94903 415-507-5000 Web: www.autodesk.com	Autodesk MapGuide Viewer	AutoCAD Map 2000	Autodesk World	Autodesk Map-Guide	NT, Mac, UNIX	ESRI SHP, ESRI ARC/INFO Coverage, Intergraph DGN, MapInfo MIF/MID, Atlas BNA, CSV (comma delimited file), AutoCAD® Release 14 DWG/DXF files, GIF, TGA, CALS, PNG, BMP, JPEG, TIFF, GeoTiff, GeoSPOT/BIL (ESRI.hdr) ESRI world files, MapInfo .TAB	Pentium-based PC, 16MB RAM, 20MB free hard disk space, and Windows 95, Windows 98, or Windows NT 4.0 (browser recom-mended but not required).	Web, Phone
Bentley Systems, Inc. 685 Stockton Drive Exton, PA 19341-0678 610-458-5000 fax: 610-458-1060 Web: www.bentley.com		GeoOutlook	MicrosStation/J (Geoengineering Configuration) MicroStation GeoGraphics	Model Server Continuum	NT			Web
Blue Marble Geographics 261 Water Street Gardiner, ME 04345 1-800-616-2725 fax: 207-582-7001 Web: www.blumarblegeo.com		GeoView			NT			GeoView
ESRI Inc. 380 New York St. Redlands, CA 92373-8100 909-793-2853 fax: 909-307-3025 Web: www.esri.com	ArcExplorer	ArcView	ARC/INFO	ArcSDE	NT, UNIX	ArcView Shapefiles, ARC/INFO coverages, ARC/INFO GRID data, TIFF, ERDAS, BSQ, BIL, BIP, Sun raster-files, RLC, ORACLE, INGRESS, SYBASE, INFORMIX, dBase III and IV, INFO tables, tab or comma separated ASCII text	Sun Solaris 2, HP 9000/700 and 8x7 series, IBM RS/6000, SGI, Digital UNIX, Digital Alpha (Win-dows NT 4.0), Intel PCs (Win-dows NT 4.0, Windows 95, and OS/2Warp Version 3.0)	Web, Phone, e-mail
Intergraph Corp. One Madison Industrial Park Huntsville, AL 35894-0001 256-730-2000 fax: 256-730-8549 Web: www.intergraph.com	GeoMedia Viewer	GeoMedia	GeoMedia Profes-sional	GeoMedia Web Map	NT, UNIX	MGE, FRAMME, ARC/INFO, ArcView, MicroStation, ORACLE Spatial Cartridge/Spatial Data Option (SC/SDO), and ACCESS data		Web, Phone, e-mail
MapInfo Corp. One Global View Troy, NY 12180 518-285-6000 fax: 5188-285-6070 Web: www.mapinfo.com	ProViewer	MapInfo Professional		MapXtreme	NT		NT 4.0 with service pack 3 (or higher recommended), One Pentium processor server (multiple processors will improve perform-ance), 128 Megabytes of RAM recommended, 64 megs of RAM minimum	Web, Phone, e-mail
Professional Geo Systems BV Damrak 44 1012 LK Amsterdam, Netherlands 31-020-422-8925 fax: 31-020-624-2624 Web: www.pgs.nl			GEO++	Lava/Magma	NT, UNIX			
Smallworld 5600 Greenwood Plaza Blvd. Englewood, CO 80111 888-779-6980 fax: 303-779-1051 Web: www.smallworldamericas.com			Smallworld 3	SmallworldWeb	NT, UNIX		Client requires Intel 80486 and Intel Pentium processor running Windows NT 4.0 or Windows 95, high resolution graphics, and 24 Megabytes of RAM. Network requires a high specification machine, 256 megabytes of RAM.	Web, Phone, e-mail

The challenge for a data warehouse design is to identify and collect all the sources of information for analysis. Current research areas focus on the use of “middle-ware” to provide data management services invisible to the user. For example, broker tools can be very useful in parsing data requests and extracting the relevant data for a report. Model brokers can evaluate the metadata and invoke the necessary data translators to place the data into a common geographic setting, then invoke a rendering module to display the selected data set.

It is unlikely that every operational system stores comparable data fields in the same form. Part of the process of collecting information is to reformat like data into compatible formats. Once the data warehouse has been created, the usefulness of the system will depend upon how easy it is to access the data. It is therefore desirable to model the data structures and standardize the formats and establish a naming convention (Hall 1999).

Ensuring data integrity and cleanliness is often the most difficult step in the overall data warehouse project. Ideally, data used from the data warehouse should be corrected at the source and then transferred back to the data warehouse. Not doing so creates several problems ranging from corrupt warehouse data, increased cost due to information needing to be scrapped and reworked, to bad data in reports and maps resulting in confusion and lack of trust (Hall 1999).

Also, it is important to measure and post the quality (completeness, validity, and accuracy) of the warehouse data. GIS users who use it must know its reliability so they can factor it into their decisions. If cleaning the data at the source is not possible, assess its quality (completeness and accuracy) to determine its reliability and need for quality improvement (Hall 1999).

Metadata is a kind of dictionary that defines data. It is valuable for locating data, explaining how to use it, and answering questions on format, sources, when it was created, and how it should be distributed. It should be a required step in any map creation (Hall 1999).

A variety of tools are available for creating standard queries and reporting and providing on-line analytical processing (OLAP) tools for multidimensional data. Technologies such as the Internet and intranets, and data mining tools can be employed to ensure all users can get the information they need when they need it (Hall 1999).

Other opportunities arising from data warehouse management include query management (e.g., caching of commonly used data), data usage tracking (for keeping track of who is using the data and how often they are using it), data refreshment tracking (monitoring how often the data warehouse is refreshed), and 'chargeback' management (for monitoring how much it costs to analyze the data in terms of system resources used) (Hall 1999).

Implementation of an Installation-Wide GIS

The implementation process should involve the user community in the development of the GIS design (Budic and Godschalk 1994). Therefore, it is necessary for all users to have a clear understanding of their GIS applications and data requirements before they are ready to develop system design specifications.

Issues in implementation must include financing, training, and commitment through staffing for ongoing operation. A successful Enterprise GIS needs a continuous flow of finances (Budic and Godschalk 1994). In determining financial considerations, include in the equation currently available financial resources as well as future performance/cost considerations.

Evaluate the framework goals established at the beginning of the process (efficiency, effectiveness, competitiveness, democracy) to develop assessment criteria. Candidate criteria include system quality, information quality and use, user satisfaction, user training, customer service (e.g., to novice users), and the impact on individual and departmental workflow.

Finally, a timeline should be developed for implementation. There are several models to use in implementing an Enterprise GIS (Budic and Godschalk 1994).

- In the 'Big Bang' approach, you initiate an instant switch. Because this approach requires major planning, it is usually centrally managed. It is a suitable application for lots of users and results in an immediate organizational change — but it can be risky.
- The 'Parallel Running' model has both the manual and automatic systems running simultaneously for some time. This model requires extra time and funding to succeed and often experiences problems with lagging organizational change. However, it is less risky than the Big Bang approach.
- The 'Phased Introduction' model introduces changes to the users gradually. It is a good model when users use the system for different functions.

It does not need a lot of planning or extra resources and has a low risk level.

- The 'Trials and Dissemination' model is good for small-scale changes such as visualizing implementation. It is not time consuming to implement and has a very low risk.
- The 'Incremental Evolution' model is slow and time consuming because it lacks planning. This can lead to dead ends and result in difficulty in transferring information.

Issues in GIS Implementation

The main obstacles to implementing an Enterprise GIS in any organization are conflict within and lack of coordination between the various departments. Data and software standards are often difficult to establish and integrate (Croswell 1991). Due to the large upfront cost of developing an Enterprise GIS, support from upper management can be hard to obtain (Wilson 1996). This makes it important to gain the support of management for the planning and implementation early in the process.

Improvement to data and data base maintenance often has limited visible effects on immediate user gratification (Wilson 1996). Lack of user training and understanding of the technology across and between departments can contribute to user apathy and fear of change (Croswell 1991).

Problems often exist within an organization in managing large databases. These include problems in database design and conversion, consistent data development, data quality, and maintenance of source materials (including responsibility for individual data sets). This can be complicated by problems with staff availability and recruitment (Croswell 1991).

Difficulties with network communication and data sharing can occur if a data broker is not implemented (Croswell 1991). Proper initial planning and hardware purchase can address this problem. Software complexity and the general maturity of the technology can also complicate the process, but training and hiring of qualified personnel should address this.

3 Conclusions

Many U.S. Army Installations have already made a large investment in network and computer hardware and GIS software. However, a comprehensive review of the organization and implementation of systems across the installation would be beneficial. This could be used to guide future information resource allocations.

Of particular concern is the development of an installation-wide data model. The data model would identify a common set of data for installation-wide use, collection and attribute standards, accuracy requirements, and maintenance plans (periodicity of updates, notification procedures, etc.). Other issues include:

- Responsibilities for developing and maintaining the data sets need to be determined and assigned.
- Access to ‘official’ copies of the data needs to be established; for example, a core data set or base information resources.
- Standardized data formats, data sources naming, and creation methods should be established.
- Metadata creation should be done (using existing metadata tools).
- Development of a standardized GPS data dictionary should be done (for future data collection purposes).
- Assessment of data broker tools, such as ESRI’s Spatial Data Engine-SDE should be made.
- Develop adaptive interfaces to facilitate the broad range of data users.

Information constitutes a critical resource for the Army. While never popular or easy, a comprehensive examination of the workflow processes associated with the creation, management, and dissemination of data (and geographic data in particular) is required to assure that the Army’s information resources are efficiently and effectively used to meet its mission requirements.

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13. ABSTRACT *(Maximum 200 words)*

In spite of the large investments in geographic information systems (GIS) technology and software by the Army and other institutions, implementation has typically occurred in more of an ad hoc manner than preferred, and more decentralized or “grass-roots” initiated than from a comprehensive information resource management perspective. Some of the problems inherent with this history include insufficiently documented data, redundant and divergently evolving data, incompatible system and file formats, and a disconnect between the capabilities and expectations of a growing user community, and the individuals and organizations historically managing these resources.

Enterprise GIS borrows from Enterprise information models used in the broader information systems industry to create a comprehensive framework for providing user information and minimizing problems due to the distributed and disaggregated implementation.

This report discusses Enterprise GIS and a comprehensive review of the organization and implementation of systems at an installation to guide future information resource allocations. An installation-wide data model should be developed to identify a common set of data for installation-wide use, collection and attribute standards, accuracy requirements, and maintenance plans (periodicity of updates, notification procedures, etc). User-appropriate interfaces should be developed to minimize unnecessary training or diversion from missional requirements.

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